RESEARCH DEPARTMENT

ADJACENT-CHANNEL REJECTION AND GENERAL PERFORMANCE OF TYPICAL AMERICAN AND GERMAN F.M. RECEIVERS

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CORRIGENDA

Appendix 1

Page 20	para 1.6	line 7
Page 21	para 1.7	line 7
Page 23	para 1.9	line 8

should each read:-

"19T8 a.m. detector, phase discriminator, audio amplifier."

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Fig.Nos.1 - 7

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Summary

In planning a v.h.f. f.m. broadcasting system, one of the most important decisions to be made is the frequency spacing between adjacent channels. Since this will depend greatly on the properties of the receivers used by the public, tests have been carried out on ten mass-produced domestic receivers of German and American manufacture. The principal results are summarised in Table 1.

Considering fringe-area conditions, where the wanted and adjacent-channel signals may occasionally have equal amplitudes, the American receivers gave satisfactory performance with a channel spacing of 200 kc/s, while the German receivers required a spacing greater than this. The German receivers could nevertheless be detuned to give sufficient discrimination against one interfering signal spaced 200 kc/s from the wanted carrier without appreciable deterioration in the wanted programme.

It is thought that the superior performance of the American receivers is due to the fact that 200 kc/s is the channel spacing used in America, whereas the German receivers were designed at a time when the f.m. service in Germany was based on a channel spacing of 400 kc/s.

It is concluded that there is no reason to adopt a spacing greater than 200 kc/s in this country.

1. Introduction

In planning a v.h.f. broadcasting system, one of the most important decisions to be made is the frequency separation between adjacent channels. If the frequencies of adjacent channels are too close together, commercial receivers will not be sufficiently selective to discriminate between them. If, on the other hand, the channel spacing is unnecessarily wide, too few channels will be available within the allotted band, and it may be necessary to site stations

operating in the same channel so close together geographically that mutual interference results. It is essential that the channel separation be decided in relation to the kind of receiver that would be sold to the public, but it is not possible at present to obtain British receivers that can be considered as typical of future mass-produced models. Experiments were therefore carried out using ten current receivers of which five were obtained from Germany and five from America. Since the radio industries in both these countries have had considerable experience in the mass production of domestic f.m. receivers, such tests should give a useful guide as to what can be done with modern design and production techniques.

One of the accepted standards for a v.h.f. broadcasting service is that the amplitude of an adjacent-channel signal may, due to anomalous propagation, become at least equal to that of the local transmission for 1% of the time. The object of the experiments described in this report was to determine whether or not the selectivity provided by a typical receiver would give sufficient protection against such interference if the channel spacing were 200 kc/s. The protection was considered to be satisfactory if an adjacent-channel signal, equal in strength to the wanted signal, gave rise to output interference of subjective grading not worse than "Perceptible".

The choice of receivers was limited to those considered suitable for use in the fringe of a service area, since it is only there that adjacent-channel interference is likely to be serious. No attempt was made to alter or improve the alignment of the receivers after delivery, but a series of general performance tests was carried out. The results are included in the report.

2. Description of receivers

The receivers chosen were all table models in the medium and upper-price classes, and they incorporated either a ratio detector or a phase discriminator. All the receivers except the cheapest German model incorporated a r.f. stage for the f.m. band. Although cheaper models were available they were not considered suitable for fringe-area reception, most of them being a.m. receivers which could be made to receive f.m. by detuning.

In addition to f.m. reception, the American models could receive a.m. in the medium-wave band only, whereas most of the German receivers covered the long-wave, medium-wave, and one or more short-wave bands.

Furthermore, the latter all embodied variable i.f. bandwidth and, in the more expensive models, bandspread tuning for short waves.

The German receivers were large table models, all but the cheapest having well-finished wooden cabinets which compared favourably with the more expensive types of British domestic receiver. They gave the impression of expensive mechanical design; the tuning drives were smooth, sensibly free from backlash and fitted with large and legible scales. In many cases quite complex mechanical systems were used to indicate the action and setting of subsidiary controls such as the i.f. bandwidth and tone controls. In sharp contrast, the American models were all in small plastic cabinets, their mechanical design appeared to have been sacrificed to cheapness, and they were in consequence far less pleasant to handle.

Each American receiver had a built-in aerial for the medium-wave band and provision was made for using the mains lead as a v.h.f. aerial in locations where this was found satisfactory. The German receivers, with the exception of the cheapest, had a dipole fitted inside the cabinet for use in the v.h.f. band. By suitable connections at the rear of these receivers this could be used for a.m. reception in areas of high field-strength.

Further details of the receivers are given in Table 1 and Appendix 1. It will be noticed that the German models have in general one valve less than the American models but this is due to the use of multiple valves and reflexing, rather than to a reduction in the number of amplifying stages.

3. General performance tests

The receivers were tested initially to assess their performance at the fringe of a service area. Since this report is concerned with f.m. only, no tests were carried out to investigate their reception of a.m.

3.1 Sensitivity

A fuller description of this test is given with the results in Appendix 2. All the receivers are sufficiently sensitive for fringe-area reception; apart from G.5, which requires an input of 210 μV, the input required to satisfy the test conditions lies between 17 μV and 72 μV.

3.2 Fidelity

The variation of output power with modulation frequency is shown in Figs. 1 and 2. These curves, which were measured with a resistive load in place of the loud-speaker, show that the high-frequency response of all the models is well maintained. This is borne out by listening tests in the case of the German receivers. Listening to the American receivers, however, there appears to be considerable attenuation of the higher audio frequencies, probably owing to the loud-speaker characteristics.

The variation of distortion with modulation depth is shown in Figs. 3 and 4. In general the level of distortion is higher in the American receivers than in the German.

3.3 Local-oscillator frequency drift

Figs. 5 and 6 show the local-oscillator frequency drift after the receivers have been switched on from cold. In the case of one German receiver, the G.4, and all the American receivers, the drift is between 35 kc/s and 75 kc/s. With the remainder of the German types the drift is greater than 100 kc/s.

3.4 Local-oscillator radiation

The results of this test are given in Appendix 3. The American receivers, with the exception of A.4, are consistently better in this respect.

3.5 Impulsive-interference performance

This test is described in Appendix 2. Three of the American receivers, A.2, A.3 and A.4 have an outstanding performance when subjected to impulsive interference. This superiority may be due in part to the lack of high-frequency response referred to in paragraph 3.2, which is particularly marked in these three receivers; but other factors must be responsible for the increasing superiority with deteriorating input signal-to-noise ratio.

4. Adjacent-channel rejection

These tests were performed to determine the relative amplitude of the interfering signal producing certain grades of interference level in the output.

Such tests can be carried out either objectively or subjectively, and though objective tests - using, for example, sinusoidal modulation - are capable of more precise repetition, the results are not usually found to agree with those of tests using typical programmes. For this reason it was decided to use subjective methods. Only three observers took part, but they were all experienced in assessing programme interference.

A block diagram of the apparatus is shown in Fig.7. The outputs of two signal generators, frequency-modulated in accordance with standard BBC transmitter practice, were combined in a resistive network connected to the aerial terminals of the receiver under test. The receivers were designed for use with a folded dipole of 300 ohms impedance, and the resistive network was therefore arranged to present this source impedance to the receiver under test. The amplitude of the wanted signal was set to an open-circuit value of 500 μV. The amplitude of the interfering signal was then varied to give the required subjective grade of interference as judged by the observer.

These grades were defined as:

JP The interference was just perceptible in the quiet passages of the wanted programme

P The interference was perceptible in the quiet passages of the wanted programme without careful listening

SD The interference was slightly disturbing when listening to the wanted programme

D The interference was disturbing

Each observer was asked to tune the receiver to the wanted signal in the absence of interference. The tuning indicator was used if one was provided, but if not, a number of tuning criteria were available:

1. Minimum distortion

2. Minimum hiss noise

3. Tuning mid-way between those points on the dial where marked increase in distortion or hiss noise occurs

With some receivers the first criterion was the only reasonable choice (usually owing to a restricted linear bandwidth in the discriminator). With other receivers (principally those having a wide discriminator but restricted top response in the audio stages) the first two criteria gave a serious ambiguity of tuning, and it was necessary to use the third. The tuning procedure used is stated above each of the appropriate tables Nos.2 to 11.

A selection of results having particular interest is included in Table 1, which gives the input carrier ratios producing the output interference grade of "Perceptible". These results, which display the asymmetry common to most f.m. receivers, show that if the grade of output interference is not to be worse than "Perceptible" when the wanted and adjacent-channel signals are of equal strength, the German receivers require a channel spacing exceeding 200 kc/s. The American receivers, on the other hand, with the exception of A.2, would be satisfactory with a spacing of 200 kc/s.

While performing these tests it was found possible with most receivers to obtain a material improvement by tuning in the presence of the interference, the amount of detuning required never being sufficient to cause appreciable distortion. Since interference of the strength postulated is likely to occur only for 1% of the total listening time, and since when it does occur it will probably persist for at least half an hour, it seems reasonable to adopt such a tuning procedure. For this reason further tests were carried out in which each receiver was switched on from cold and tuned to the wanted signal in the presence of interference spaced from it by 200 kc/s. For all receivers an output interference grade of "Perceptible" was obtained with the interfering carrier level equal to or greater than the wanted signal. The results, which are given in the two right-hand columns of Table 1, show considerable improvement over those obtained previously. Eight out of the ten receivers maintained acceptable quality and interference level over a test period of thirty minutes but the remaining two (both German) required retuning after some five minutes. This was occasioned by local-oscillator drift, which caused distortion of the wanted programme whether the interference was present or not.

In a few cases the results of the second series of tests show a performance inferior to that obtained in the first series, owing to the effect of local-oscillator frequency drift. Nevertheless all the receivers give satisfactory results when tuned in the presence of

an interfering signal equal in amplitude to the wanted carrier and spaced 200 kc/s from it.

In order to check the conclusions reached as a result of the laboratory experiments, further tests were made using two transmitters whose carriers were spaced by 200 kc/s and adjusted in amplitude to produce equal field strengths at the receiving aerial. The transmitters were installed at Nightingale Square, the receiving aerial being at Kingswood Warren where the field strength was approximately 250 µV/m. It was found that all the receivers were capable of selecting either of the two transmissions satisfactorily.

5. Intermediate-frequency selectivity

Each receiver had at least two pairs of coupled circuits, excluding the discriminator, at the intermediate frequency of 10.7 Mc/s. Although four receivers each had at least one additional tuned circuit they were not, as a group, superior to the others in their adjacent-channel rejection. The i.f. response curves of all the receivers were measured, and it was found that those with more tuned circuits did not necessarily have greater attenuation at ± 200 kc/s off tune.

In respect of the attenuation of the i.f. circuits at ± 200 kc/s the receivers fell into two definite groups. One group consisting of receivers having an attenuation between 18 and 22 db, included one of the German (G.2) and all the American receivers. In the case of the other group, comprising the remaining German receivers, the attenuation at ± 200 kc/s was between 9 and 11 db. While there is no clear line of demarcation between the adjacent-channel rejection provided by these two groups, the receivers with greater attenuation at ± 200 kc/s are in general superior. Nevertheless off-tune attenuation is by no means the only factor contributing to the observed result. For example, although the two American receivers A.2 and A.5 had similar i.f. response curves the adjacent-channel rejection of A.5 is markedly superior. It is in fact superior to all the other receivers even though it has only two pairs of coupled circuits.

The four German receivers having the smaller attenuation at ± 200 kc/s employ tuned circuits with "Q" factors of about 55 and coupling factors "kQ" of about 1.3. The resulting bandwidth is unnecessarily wide for the system deviation, but was probably provided to allow for oscillator drift. The remaining receivers have

critically-coupled circuits with mean Q values of about 70, giving an adequate bandwidth with improved attenuation at $\pm$ 200 kc/s, but without sacrifice of gain or increased cost. The German receiver G.2, which adopts this technique, is the second cheapest of the German models.

6. Conclusions

Used with a service employing a 200 kc/s channel spacing, four out of the five American receivers would give an output interference level better than "Perceptible" when subjected to an adjacent-channel signal equal in amplitude to the wanted signal. The remaining American receiver and all the German receivers would require to be detuned slightly in order to reject such interference, but the degree of detuning would not be sufficient to cause appreciable deterioration of the wanted programme. This solution would not of course be applicable if adjacent-channel interference were to occur on both sides of the wanted carrier simultaneously. It is, however, probable that some degree of protection against at least one of the interfering signals would be provided by the directivity of the receiving aerial.

Two of the German receivers would require to be retuned five minutes after switching on whether the interference is present or not, since drift of the local-oscillator frequency causes distortion of the wanted programme.

Current German practice is apparently to make the i.f. bandwidth sufficient for an excessive local-oscillator drift (nevertheless one German receiver had an extremely low oscillator drift - 37 kc/s). The Americans appear to have restricted the oscillator drift at no obvious extra cost and have made the bandwidth sufficient only for the system deviation. The relatively inferior performance of the German receivers in the tests described may well be due to the fact that they were designed for the present v.h.f. broadcasting system in Germany which uses a channel spacing of 400 kc/s.

All the receivers tested have a sensitivity permitting their use in fringe areas, and in most cases they could be used with a simple indoor aerial. The performance of the American receivers under conditions of impulsive interference is extremely good.

TABLE 1

Receiver details and adjacent-channel rejection figures

Receiver	Price	Total No. of Valves	Valves used for f.m.	Coupled pairs before discrim.	Type of discriminator	Oscillator drift in kc/s		(Input interference)/(wanted carrier) ratio in db for output grade of "Perceptible" at carrier frequency spacing shown at top of columns: Interference applied after tuning the receiver							Receiver tuned in presence of interference	
						After 3 mins	Max drift	-400 kc/s	-300 kc/s	-200 kc/s	0 - 1 kc/s	200 kc/s	300 kc/s	400 kc/s	-200 kc/s	200 kc/s
German G.1.	DM.508	7*	7*	2	Ratio detector	85	135	14	0	-9	-35	4	15	26	5	10
German G.2.	DM.308	6*	6*	2	Ratio detector	92	115	22	11	-3	-26	10	22	28	0	10
German G.3.	DM.328	6*	6*	2	Ratio detector	115	175	20	8	-3	-38	2	10	19	2†	2†
German G.4.	DM.408	6*	6*	2½	Ratio detector	33	37	> 30	28	13	-36	-12	-5	7	10	5
German G.5.	DM.228	6	6	2	Ratio detector	60	122	> 30	24	7	-24	-22	-11	4	10†	5†
American A.1.	$ 85	7	7	3	Limiter and phase discrim.	42	57	> 30	23	4	-18	3	19	> 30	10	10
American A.2.	$ 60	7	7	2½	Limiter and phase discrim.	16	70	> 30	22	9	-19	-12	4	18	0	0
American A.3.	$ 60	7	7	2	Ratio detector	36	62	> 30	23	6	-31	2	19	30	5	10
American A.4.	$ 60	8	7	2½	Limiter and phase discrim.	37	74	27	15	1	-25	2	13	25	3	10
American A.5.	$ 79	7	7	2	Ratio detector	62	62	> 30	> 30	18	-28	5	21	> 30	10	10

NOTES The rectifier is not included in the number of valves.

* These receivers included a magic eye tuning indicator. This is not included in the number of valves.

† These receivers required retuning after some five minutes because of oscillator drift.

Adjacent-channel rejection

TABLE 2

Receiver G.1

Normal tuning using magic eye

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	19	5	-5	-21	8	18	28
	SD	17	3	-7	-26	6	17	27
	P	14	0	-9	-35	4	15	26
	JP	9	-3	-13	-44	3	12	23

TABLE 3

Receiver G.2

Normal tuning using magic eye

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	27	14	2	-11	14	26	>30
	SD	25	13	0	-17	12	24	>30
	P	22	11	-3	-26	10	22	28
	JP	17	8	-5	-33	9	18	24

Adjacent-channel rejection

TABLE 4

Receiver G.3

Normal tuning using magic eye

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	26	11	-1	-23	7	15	24
	SD	23	9	-2	-31	5	12	21
	P	20	8	-3	-38	2	10	19
	JP	16	5	-6	-43	-1	8	17

TABLE 5

Receiver G.4

Normal tuning using magic eye

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	>30	>30	16	-19	-4	6	16
	SD	>30	30	15	-26	-7	2	13
	P	>30	28	13	-36	-12	-5	7
	JP	28	23	12	-40	-17	-10	1

Adjacent-channel rejection

TABLE 6

Receiver G.5

Normal tuning to minimum hiss-noise level

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	>30	29	18	-13	-17	-6	11
	SD	>30	28	14	-20	-19	-9	8
	P	>30	24	7	-24	-22	-11	4
	JP	>30	21	3	-31	-24	-14	0

TABLE 7

Receiver A.1

Tuning midway between points where a marked increase in hiss noise occurred

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	>30	29	13	-5	8	27	>30
	SD	>30	27	9	-10	6	23	>30
	P	>30	23	4	-18	3	19	>30
	JP	>30	19	1	-28	-2	16	>30

Adjacent-channel rejection

TABLE 8

Receiver A.2

Normal tuning to minimum hiss-noise level

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	> 30	30	12	-8	-7	10	27
	SD	> 30	26	10	-13	-9	7	21
	P	> 30	22	9	-19	-12	4	18
	JP	30	17	5	-26	-16	0	13

TABLE 9

Receiver A.3

Normal tuning to minimum hiss-noise level

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	> 30	30	19	-15	7	24	> 30
	SD	> 30	27	13	-21	6	23	> 30
	P	> 30	23	6	-31	2	19	30
	JP	30	18	0	-40	-2	15	27

Adjacent-channel rejection

TABLE 10

Receiver A.4

Normal tuning to minimum hiss-noise level

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	>30	19	7	-13	5	17	29
	SD	30	17	4	-18	4	15	27
	P	27	15	1	-25	2	13	25
	JP	23	11	-2	-33	-3	10	22

TABLE 11

Receiver A.5

Normal tuning to minimum hiss-noise level

Frequency of interfering signal relative to wanted signal, kc/s		-400	-300	-200	0 - 1	200	300	400
Relative amplitude of interfering signal in db to give the output subjective grade	D	>30	>30	21	-15	9	24	>30
	SD	>30	>30	20	-19	7	23	>30
	P	>30	>30	18	-28	5	21	>30
	JP	>30	28	13	-35	1	19	>30

APPENDIX 1

1. Valve types, wavebands, etc. of the receivers used

1.1 Receiver G.1

The valves used are:-

EF 80	r.f. amplifier, in circuit for f.m. only.
EF 80	self oscillating mixer, in circuit for f.m. only.
ECH 42	i.f. amplifier for f.m. and mixer for a.m. bands.
EBF 80	i.f. amplifier for all bands and detector for a.m. bands.
EB 41	ratio detector in circuit for f.m. only.
EF 40	audio amplifier for all bands.
EL 12	output valve.
EM 4	magic eye.

A bridge-connected metal rectifier supplies the total h.t. current.

The wave-bands covered are:

Long waves	750 - 2000 metres
Medium waves	186 - 590 metres
Short waves	16 - 52 metres
V.H.F. band	87 - 100 Mc/s (f.m.)

The input circuit for the v.h.f. band is nominally balanced and of impedance 300 ohms.

The intermediate frequency for the a.m. broadcast bands is 472 kc/s and for the v.h.f. band is 10.7 Mc/s.

The mains transformer has a tapped primary for use with supply voltages 110 to 240 V a.c., 50 c/s.

The overall dimensions are 25" x 11" x 16½" high and the receiver weighs 35½ lbs.

1.2 Receiver G.2

The valves used are :-

EF 80	r.f. amplifier in circuit for f.m. only.
ECH 42	frequency changer for all bands.
EF 41	i.f. amplifier for f.m. and audio amplifier for all bands.
EAF 42	i.f. amplifier for all bands and a.m. detector.
EAA 91	ratio detector in circuit for f.m. only.
EL 41	output valve.
EM 11	magic eye.

A bridge-connected metal rectifier supplies the total h.t. current.

The wave-bands covered are :-

Long waves	715 - 2000	metres
Medium waves	183 - 583	metres
Short waves	24 - 52	metres
V.H.F. band	87.5 - 100	Mc/s (f.m.)

The input circuit for the v.h.f. band is nominally balanced and of impedance 300 ohms.

The intermediate frequency for the a.m. broadcast bands is 472 kc/s and for the v.h.f. band is 10.7 Mc/s.

The mains transformer has a tapped primary for use with supply voltages from 110 to 240 V a.c., 50 c/s.

The overall dimensions are $22\frac{1}{2}$" x $10\frac{1}{2}$" x 14" high and the receiver weighs $23\frac{1}{2}$ lbs.

1.3 Receiver G.3

The valves used are :-

EF 80 r.f. amplifier in circuit for f.m. only.

ECH 81 frequency changer for all bands.

EF 41 i.f. amplifier for all bands.

EF 41 i.f. amplifier for f.m.

EABC 80 a.m. detector, ratio detector, audio amplifier.

EL 41 output valve.

EM 34 magic eye.

A half-wave metal rectifier supplies the total h.t. current.

The wave-bands covered are :-

Long waves 880 - 2000 metres

Medium waves 183 - 581 metres

Short waves 18 - 51 metres

V.H.F. band 85 - 100 Mc/s (f.m.)

The input circuit for the v.h.f. band is nominally balanced and of impedance 300 ohms.

The intermediate frequency for the a.m. broadcast bands is 473 kc/s and for the v.h.f. band is 10.7 Mc/s.

The mains transformer has a tapped primary for use with supply voltages from 110 to 240 V a.c., 50 c/s.

The overall dimensions are 22" x 12" x 14½" high and the receiver weighs 25½ lbs.

1.4 Receiver G.4

The valves used are :-

EF 85	r.f. amplifier for f.m. only.
ECH 81	self-oscillating mixer and i.f. stage for f.m., frequency changer for a.m.
ECH 81	hexode section - i.f. stage for all bands triode section - audio stage for f.m. only.
EF 85	i.f. amplifier for all bands.
EABC 80	a.m. detector, ratio detector, audio amplifier.
EL 41	output valve.
EM 34	magic eye.

A bridge-connected metal rectifier supplies the total h.t. current.

The wave-bands covered are :-

Long waves 940 - 2000 metres

Medium waves 184 - 588 metres

Short waves 13 - 22.2 metres

and 22.6 - 50.8 metres

V.H.F. band 84 - 102 Mc/s (f.m.)

The input circuit for the v.h.f. band is nominally balanced and of impedance 240 ohms.

The intermediate frequency for the a.m. broadcast bands is 473 kc/s and for the v.h.f band is 10.7 Mc/s.

The mains transformer has a tapped primary for use with supply voltages from 110 to 240 V a.c., 50 c/s.

The overall dimensions are 23" x 10" x 15" high and the receiver weighs 26 lbs.

1.5 Receiver G.5

The valves used are :-

ECH 42	frequency changer for all bands.
EF 41	i.f. stage for f.m. only.
EF 41	i.f. stage for all bands.
EB 41	ratio detector, in circuit for f.m. only.
EBC 41	a.m. detector and audio amplifier for all bands.
EL 41	output valve.

A bridge-connected metal rectifier supplies the total h.t. current.

The wave-bands covered are :-

Medium waves	185 - 588 metres
Short waves	29.4 - 50.5 metres
V.H.F. band	85 - 100 Mc/s (f.m.)

The input circuit for the v.h.f. band is nominally balanced and of impedance 280 ohms.

The intermediate frequency for the a.m. broadcast bands is 468 kc/s and for the v.h.f. band is 10.7 Mc/s.

The mains transformer has a tapped primary for use with supply voltages from 110 to 240 V a.c., 50 c/s.

The overall dimensions are 21" x 8½" x 13" high and the receiver weighs 19 lbs.

1.6 Receiver A.1

The valves used are :-

6BJ6 r.f. amplifier for both bands.

12AT7 oscillator and mixer for both bands.

6BJ6 i.f. stage for both bands.

12BA6 i.f. stage for both bands.

12AU6 limiter, in use for f.m. only.

19T8 a.m. detector, ratio detector, audio amplifier.

35C5 output valve.

A half-wave metal rectifier supplies the total h.t. current.

The wave-bands covered are :-

Medium waves 158 - 555 metres (a.m.)

V.H.F. band 88 - 108 Mc/s (f.m.)

The input circuit for the v.h.f. band is unbalanced and of 270 ohms nominal impedance.

The intermediate frequency for the a.m. broadcast band is 455 kc/s and for the v.h.f. band is 10.7 Mc/s.

The receiver is an a.c./d.c. model designed for a nominal supply voltage of 117 V.

The overall dimensions are 15" x 8" x 9" high and the receiver weighs 11 lbs.

1.7 Receiver A.2

The valves used are :-

6BJ6	r.f. amplifier for all bands.
12AT7	oscillator and mixer for f.m. and oscillator for a.m.
12AU6	i.f. stage for f.m. and mixer for a.m.
12BA6	i.f. stage for all bands.
12AU6	limiter, in use for f.m. only.
19T8	a.m. detector, ratio detector, audio amplifier.
35C5	output valve.

A half-wave metal rectifier supplies the total h.t. current.

The wavebands covered are :

Medium waves	187 - 600 metres (a.m.)
V.H.F. band	88 - 108 Mc/s (f.m.)

The input circuit for the v.h.f. band is of nominal impedance 300 ohms.

The intermediate frequence for the a.m. broadcast band is 455 Kc/s and for the v.h.f. band is 10.7 Mc/s.

The receiver is an a.c./d.c. model designed for a nominal supply voltage of 117 V.

The overall dimensions are 12½" x 8" x 8" high and the receiver weighs 8 lbs.

1.8 Receiver A.3

The valves used are :-

6BJ6	r.f. amplifier for f.m. only.
12AT7	oscillator and mixer for both bands.
12BA6	i.f. stage for both bands.
12BA6	i.f. stage for both bands.
12AL5	ratio detector, in circuit for f.m. only.
12AV6	detector for a.m. and audio stage for both bands.
50C5	output valve.

A half-wave metal rectifier supplies the total h.t. current.

The wavebands covered are :-

Medium waves	187 - 545 metres (a.m.)
V.H.F. band	88 - 108 Mc/s (f.m.)

The input circuit for the v.h.f. band is of nominal impedance 300 ohms.

The intermediate frequency for the a.m. broadcast band is 455 kc/s and for the v.h.f. band is 10.7 Mc/s.

The receiver is an a.c./d.c. model designed for a nominal supply voltage of 117 V.

The overall dimensions are $14\frac{1}{2}$" x 8" x 9" high and the receiver weighs 8 lbs.

1.9 Receiver A.4

The valves used are :-

6BJ6	r.f. amplifier for f.m. only.
12AT7	oscillator and mixer for f.m. only.
12BE6	frequency changer for a.m. only.
6BJ6	i.f. stage for both bands.
6BJ6	i.f. stage, in use for f.m. only.
6BH6	limiter, in use for f.m. only.
19T8	a.m. detector, ratio detector, audio amplifier.
50L6	output valve.

A half-wave metal rectifier supplies the total h.t. current.

The wave-bands covered are :

Medium waves	187 - 545 metres (a.m.)
V.H.F. band	88 - 108 Mc/s (f.m.)

The input circuit for the v.h.f. band is unbalanced and of nominal impedance 300 ohms.

The intermediate frequency for the a.m. broadcast band is 455 kc/s and for the v.h.f. band is 10.7 Mc/s.

The receiver is an a.c./d.c. model designed for a nominal supply voltage of 115 V.

The overall dimensions are $13\frac{1}{2}$" x $7\frac{1}{2}$" x 8" high and the receiver weighs 9 lbs.

1.10 Receiver A.5

The valves used are :-

6CB6	r.f. amplifier for both bands.
6X8	frequency changer for both bands.
6BA6	i.f. stage for both bands.
6AU6	i.f. stage in circuit for f.m. only.
6AL5	ratio detector.
6AV6	a.m. detector and audio amplifier.
6V6	output valve.
5Y3	rectifier valve.

The wave-bands covered are :-

Medium waves	187 - 545 metres (a.m.)
V.H.F. band	88 - 108 Mc/s (f.m.)

The input circuit for the v.h.f. band is unbalanced and of nominal impedance 300 ohms.

The intermediate frequency for the a.m. broadcast band is 455 kc/s and for the v.h.f. band is 10.7 Mc/s.

The receiver is designed for a supply voltage of 115 V a.c., 60 c/s.

The overall dimensions are 16" x 9" x 10" high and the receiver weighs 18½ lbs.

APPENDIX 2

General Receiver Tests

1. Sensitivity

The sensitivity of a receiver may be defined as the minimum amplitude of the input signal for a satisfactory listening level sufficiently free from distortion and receiver noise. It is convenient to find the minimum input signal which satisfies each of these requirements separately and then to take the greatest as the sensitivity figure.

The absolute sensitivity is the minimum input signal which, frequency modulated to 47.5% at 2 kc/s,* produces an output power of 50 mW when the gain control is set at maximum.

The sensitivity for sufficiently-low harmonic distortion is given by the smallest signal, modulated to 100% at 400 c/s, which gives a distortion factor of 10% when the receiver gain control is set to give an output power of 50 mW.

The sensitivity in terms of noise level is the minimum input signal, modulated to 47.5% at a frequency of 2 kc/s, which gives a r.m.s. signal-to-noise ratio of 40 db measured through an aural network.

The results of these tests, together with the maximum figure for each receiver, are given in Table 12.

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* The figure of 47.5% is the value at 2 kc/s, allowing for the effect of pre-emphasis, that is equivalent to the average modulation of a broadcast programme.

2. Local-oscillator frequency drift

For this test each receiver was switched on from cold and the oscillator frequency was measured at suitable intervals. Figs. 5 and 6 show the frequency drift which takes place from 30 seconds after switching on.

3. Local-oscillator radiation

Table 13 shows the voltage at the local-oscillator frequency developed across a 300 ohm resistor connected to the input terminals of each receiver.

4. Impulsive-interference tests

Since a calibrated source of impulsive interference suitable for use at about 90 Mc/s was not available, it was decided to use an uncalibrated source and to make the test one of comparison with an experimental receiver (Receiver B) whose performance in the presence of impulsive interference had hitherto been considered to be excellent.

A signal generator modulated with programme according to standard BBC transmitter practice and adjusted to give an open circuit voltage of 1 mV, was connected to each receiver in turn together with the source of impulsive interference. The amplitude of the interference was adjusted to produce the same subjective grades of output interference as defined in Section 4 of the present report. The corresponding input interference amplitudes relative to those required for Receiver B are given in Table 14.

TABLE 12

Sensitivity

Receiver	Sensitivity for 50 mW output	Sensitivity for 10% distortion	Sensitivity for 40 db signal/noise ratio	Sensitivity
G.1	27 µV	12 µV	58 µV	58 µV
G.2	12 µV	19 µV	37 µV	37 µV
G.3	29 µV	50 µV	54 µV	54 µV
G.4	*	19 µV	21 µV	21 µV
G.5	25 µV	38 µV	210 µV	210 µV
A.1	20 µV	64 µV	43 µV	64 µV
A.2	6 µV	72 µV	59 µV	72 µV
A.3	4 µV	45 µV	27 µV	45 µV
A.4	8 µV	52 µV	46 µV	52 µV
A.5	6 µV	17 µV	16 µV	17 µV

* With zero signal input and the r.f. gain of the receiver consequently at its maximum value, the noise output of the receiver exceeds 50 mW. No figure can therefore be quoted.

TABLE 13

Local-oscillator radiation

Receiver	Voltage across 300 ohms	Power into 300 ohms
G.1	7.5 mV	0.2 μW
G.2	18.5 mV	1.2 μW
G.3	36.0 mV	4.3 μW
G.4	24.5 mV	2.0 μW
G.5	200.0 mV	133.0 μW
A.1	5.6 mV	0.1 μW
A.2	1.2 mV	0.0045 μW
A.3	1.1 mV	0.004 μW
A.4	37.0 mV	4.6 μW
A.5	1.2 mV	0.0045 μW

TABLE 14

Impulsive-Interference Performance

Receiver	Impulsive interference input amplitude relative to that of Receiver B for the four output grades of interference			
	JP	P	SD	D
G.1	0	0	0	-11
G.2	+2	+2	+1	-16
G.3	-2	0	+1	-17
G.4	0	0	-2	-20
G.5	0	+1	-2	-2
A.1	Not performed on this receiver			
A.2	+7	+13	+29	would not become disturbing
A.3	+9	+12	+16	
A.4	+4	+7	+9	-2
A.5	-1	+2	+2	-13
B	0	0	0	0

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APP'D D.J.W.

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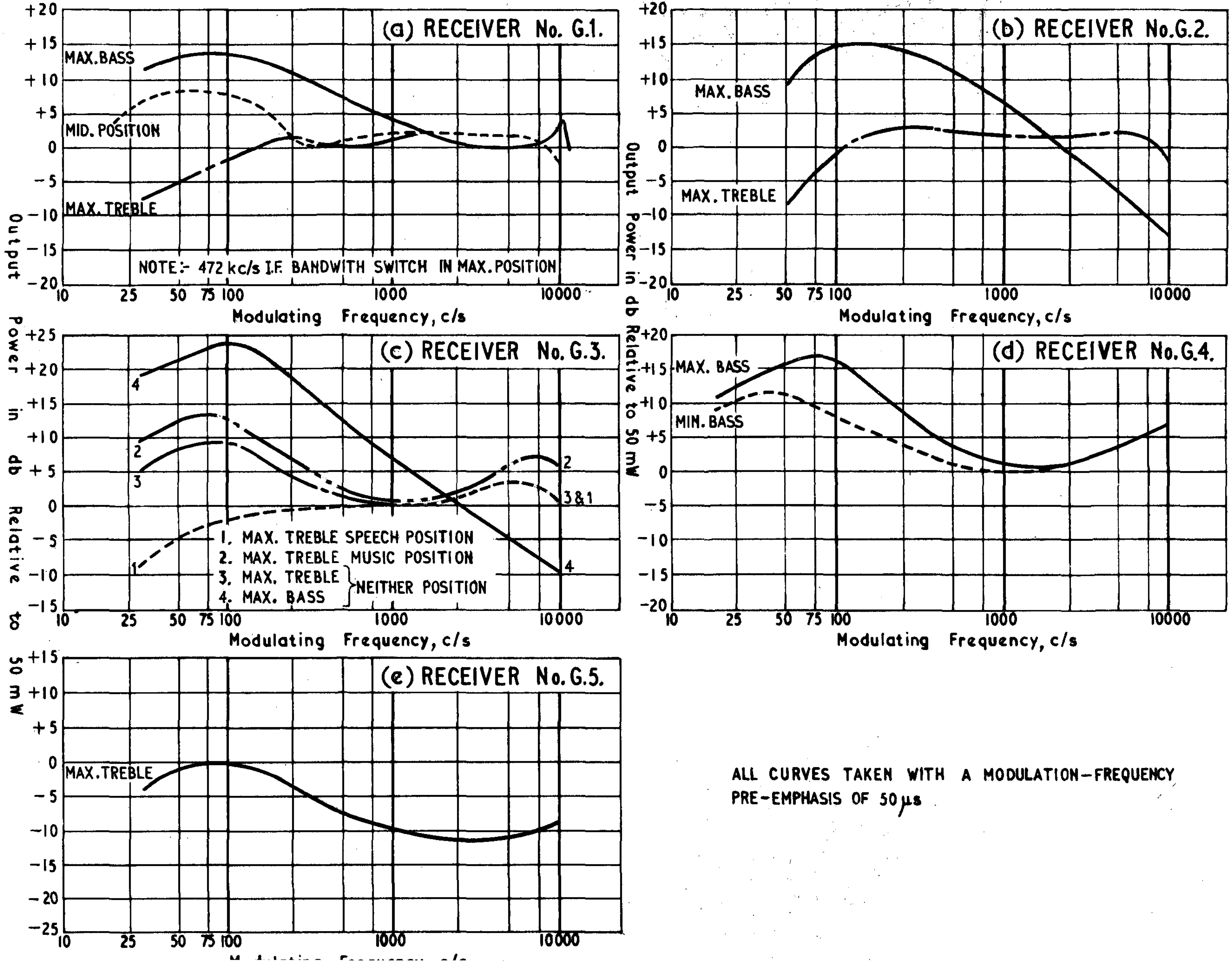
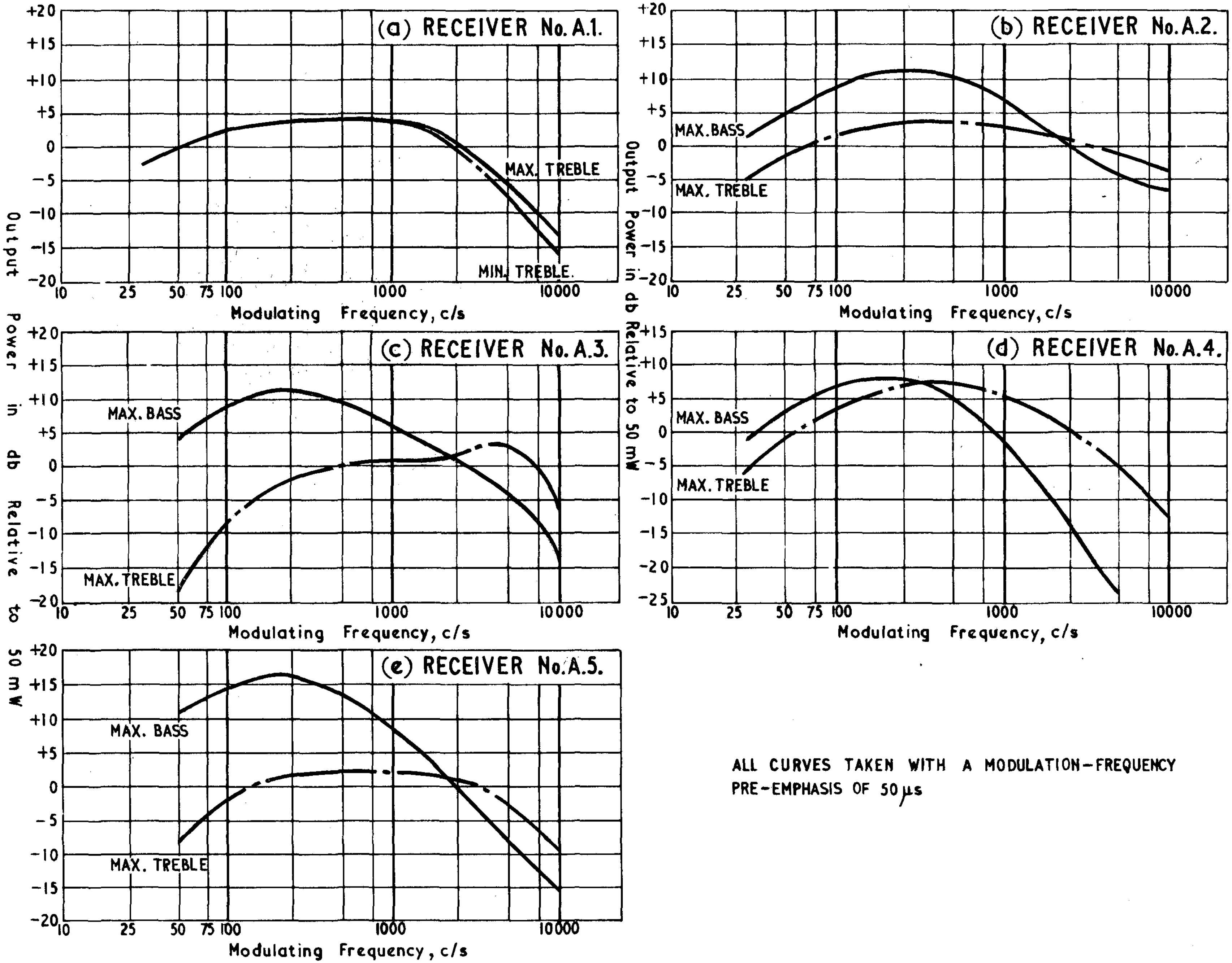


ALL CURVES TAKEN WITH A MODULATION-FREQUENCY PRE-EMPHASIS OF 50 μs

FIG. 1

AUDIO-FREQUENCY RESPONSE. GERMAN RECEIVERS



ALL CURVES TAKEN WITH A MODULATION-FREQUENCY PRE-EMPHASIS OF 50 µs

FIG. 2

AUDIO-FREQUENCY RESPONSE. AMERICAN RECEIVERS

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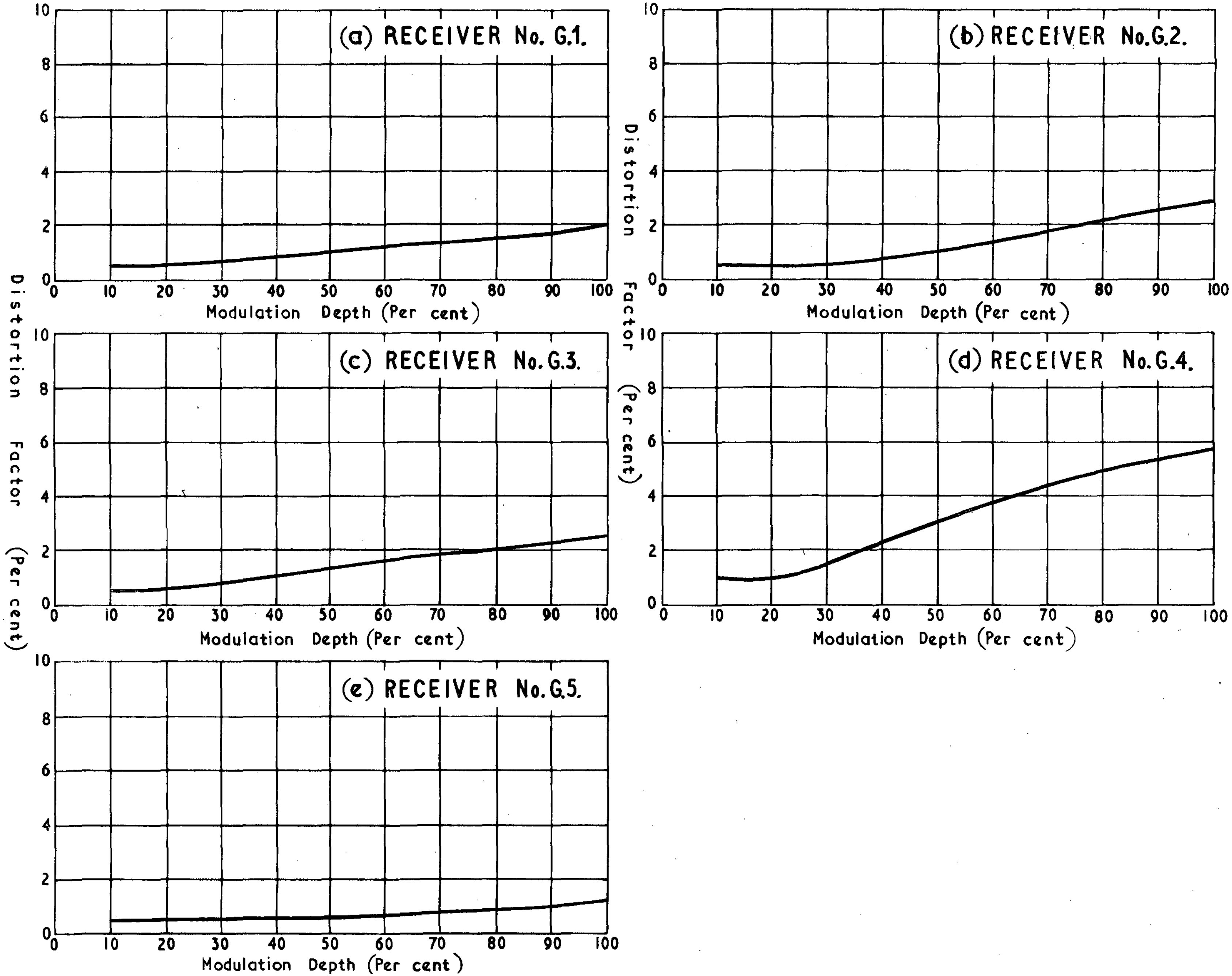

FIG.3

VARIATION OF DISTORTION FACTOR WITH MODULATION DEPTH. GERMAN RECEIVERS

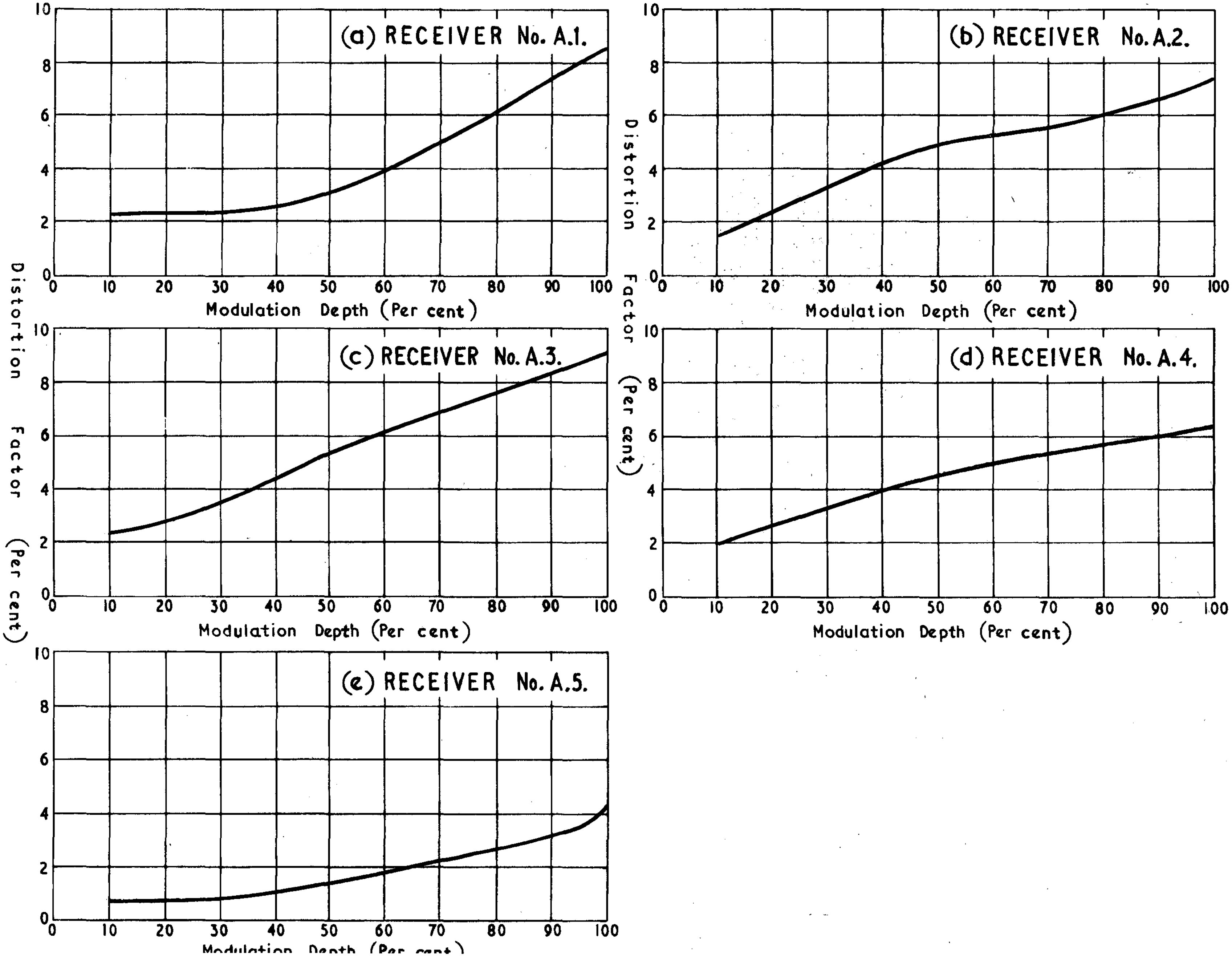

FIG.4

VARIATION OF DISTORTION FACTOR WITH MODULATION DEPTH. AMERICAN RECEIVERS

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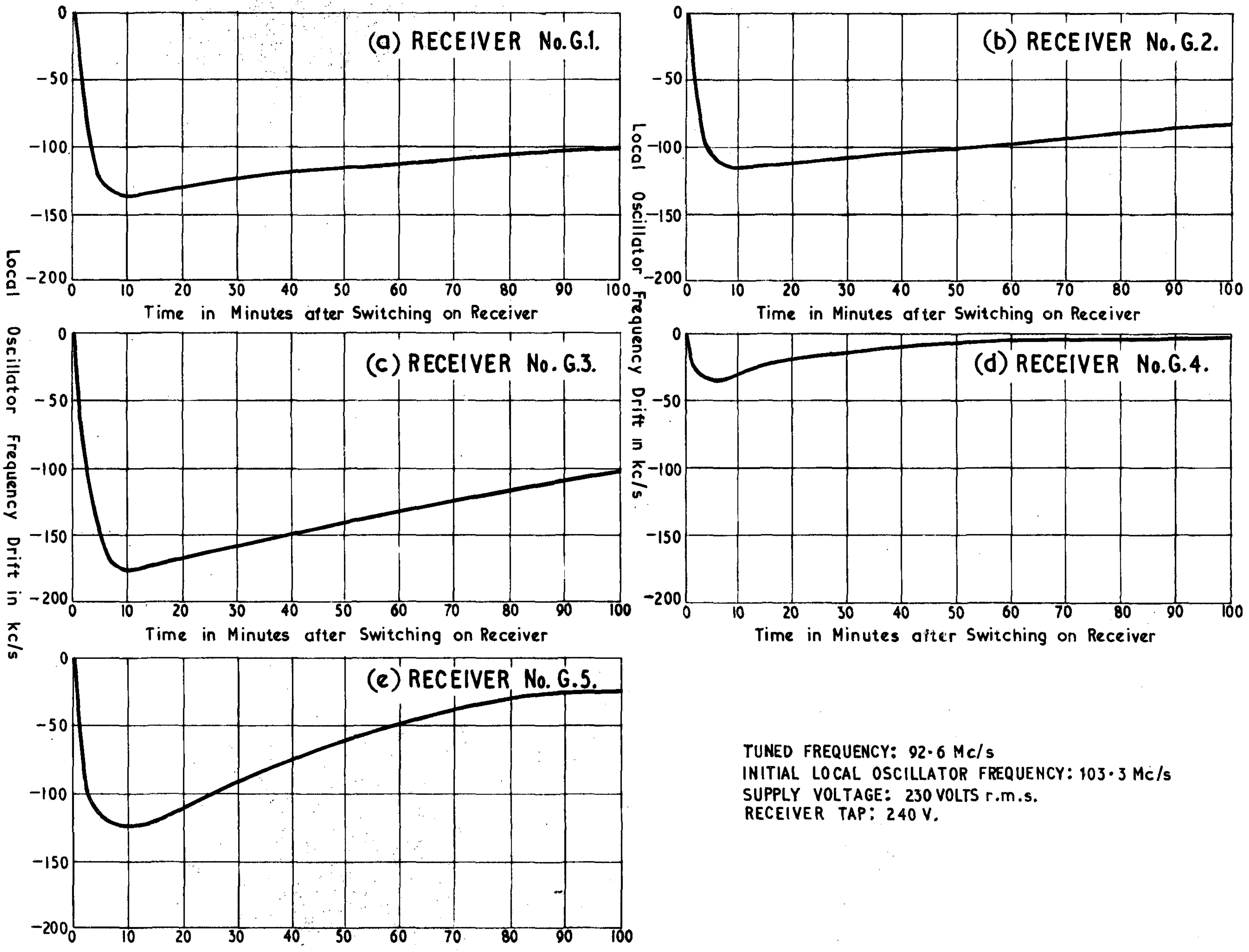
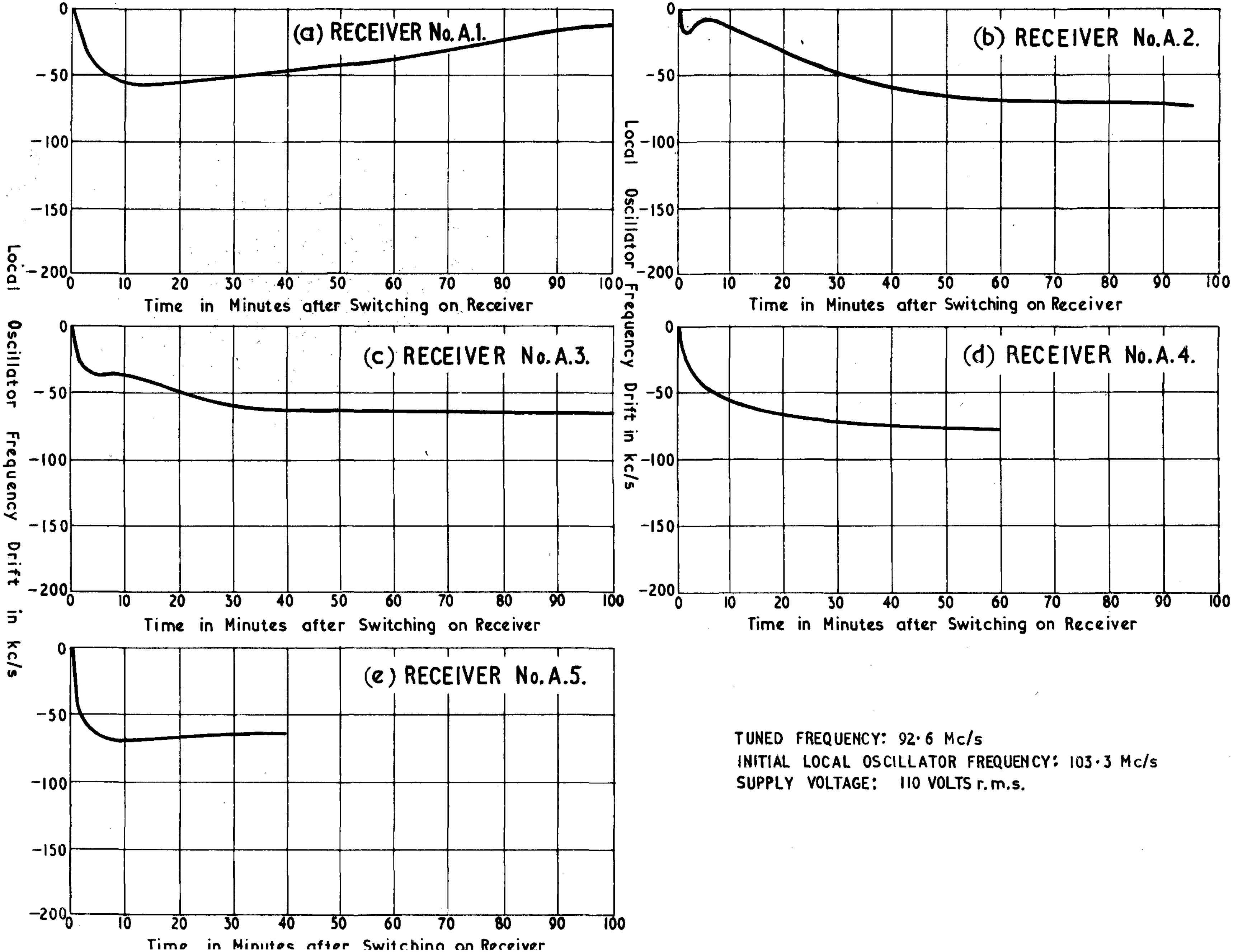


TUNED FREQUENCY: 92·6 Mc/s
INITIAL LOCAL OSCILLATOR FREQUENCY: 103·3 Mc/s
SUPPLY VOLTAGE: 230 VOLTS r.m.s.
RECEIVER TAP: 240 V.

FIG.5

FREQUENCY DRIFT OF LOCAL OSCILLATOR. GERMAN RECEIVERS



TUNED FREQUENCY: 92·6 Mc/s
INITIAL LOCAL OSCILLATOR FREQUENCY: 103·3 Mc/s
SUPPLY VOLTAGE: 110 VOLTS r.m.s.

FIG.6.

FREQUENCY DRIFT OF LOCAL OSCILLATOR. AMERICAN RECEIVERS

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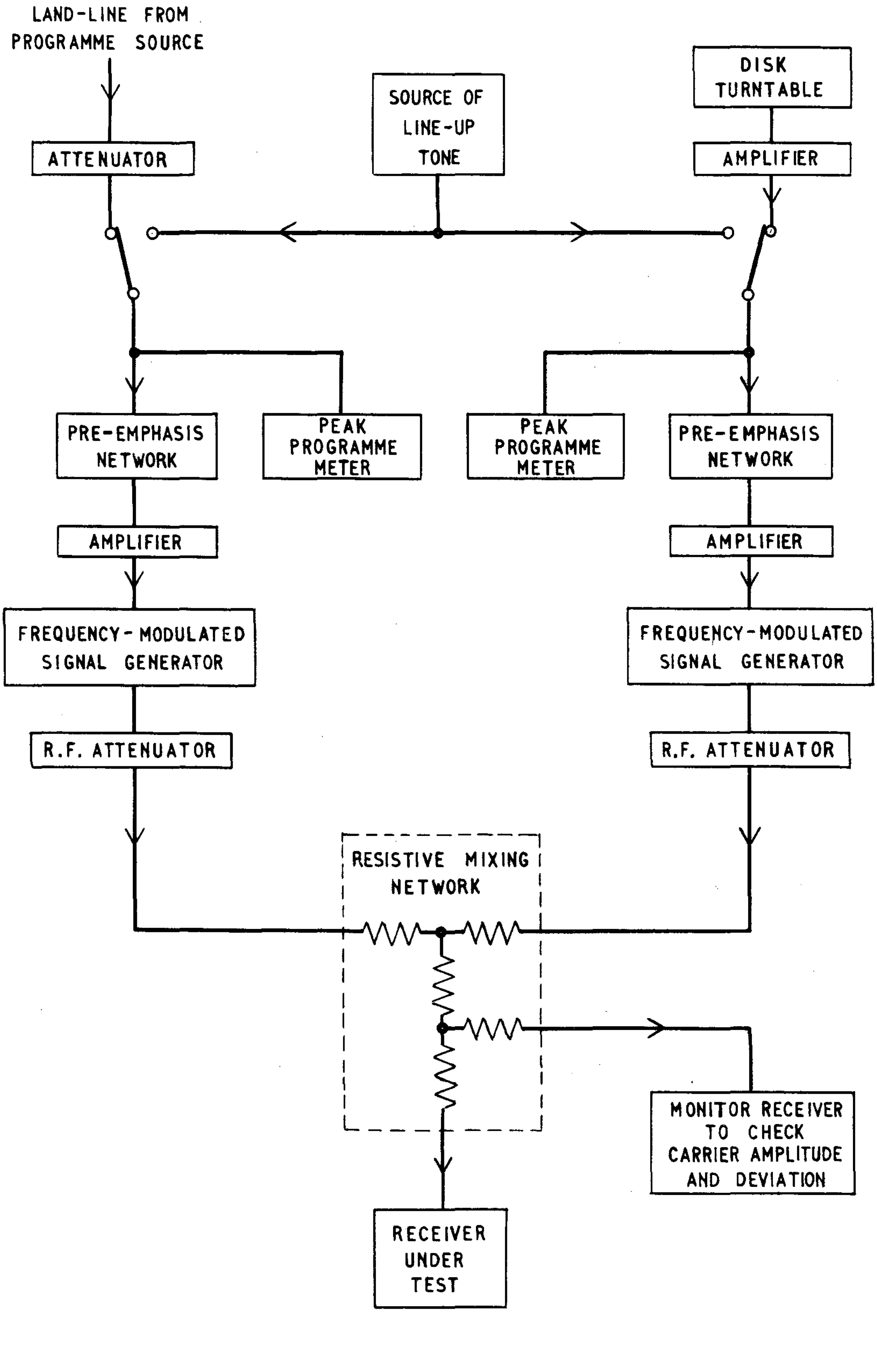

FIG.7

BLOCK SCHEMATIC DIAGRAM OF EXPERIMENTAL LAYOUT

<u>KEY</u>

G.1	Saba Bodensee Export W
G.2	Braun W.300 U.K.W.
G.3	Loewe Opta 1553 W
G.4	Mende 400-10
G.5	Grundig 1006 W.K.
A.1	Zenith G.725
A.2	G.E. 409
A.3	Westinghouse H.370T7
A.4	Emerson 659
A.5	R.C.A. Victor 1R.81
B.	Fitton a.m./f.m.